Radial Velocity Studies and Orbital Element Distributions

Roger Griffin

The Observatories
University of Cambridge

EXTRASOLAR PLANETARY DETECTION WORKSHOP

University of California
Santa Cruz Campus

March 24-25, 1976

AGENDA

Wednesday, March 24

9:30 a.m.	Welcome	G. HERBIG
9:35 a.m.	Comments Concerning the Workshop	D. BLACK
9:40 a.m.	Opening Remarks by Chairman	J. GREENSTEIN
10:05 a.m.	Feasibility of Detecting Extrasolar Planets Using Radial Velocity Observations	R. GRIFFIN
11:00 a.m.	Coffee	
11:15 a.m.	More on Radial Velocity Observations and Their Limitations	K. SERKOWSKI
12:00 noon	Lunch	
1:00 p.m.	A Brief Review of Hill's Observations of Solar Variation	N. WOOLF
1:15 p.m.	Instabilities of Solar Velocities on all Time Scales	B. HOWARD
1:45 p.m.	Feasibility of Detecting Extrasolar Planets Using Apodized Telescopes	B. OLIVER
2:15 p.m.	Limits of Astrometric Observations in the Detection of Extrasolar Planets	G. GATEWOOD
2:45 p.m.	Detection of Extrasolar Planets Using Photoelectric Astrometric Observations	F. DRAKE
3:05 p.m.	Coffee	
3:15 p.m.	Detection of Extrasolar Planets Using Optical Amplitude Interferometry	D. CURRIE
3:35 p.m.	Feasibility of Detecting Extrasolar Planets Using VLBI Observations	T. CLARK
3:55 p.m.	Feasibility of Detecting Extrasolar Planets Using IR Interferometry	C. TOWNES

M I N U T E S

FIRST WORKSHOP ON EXTRASOLAR PLANETARY DETECTION

held at

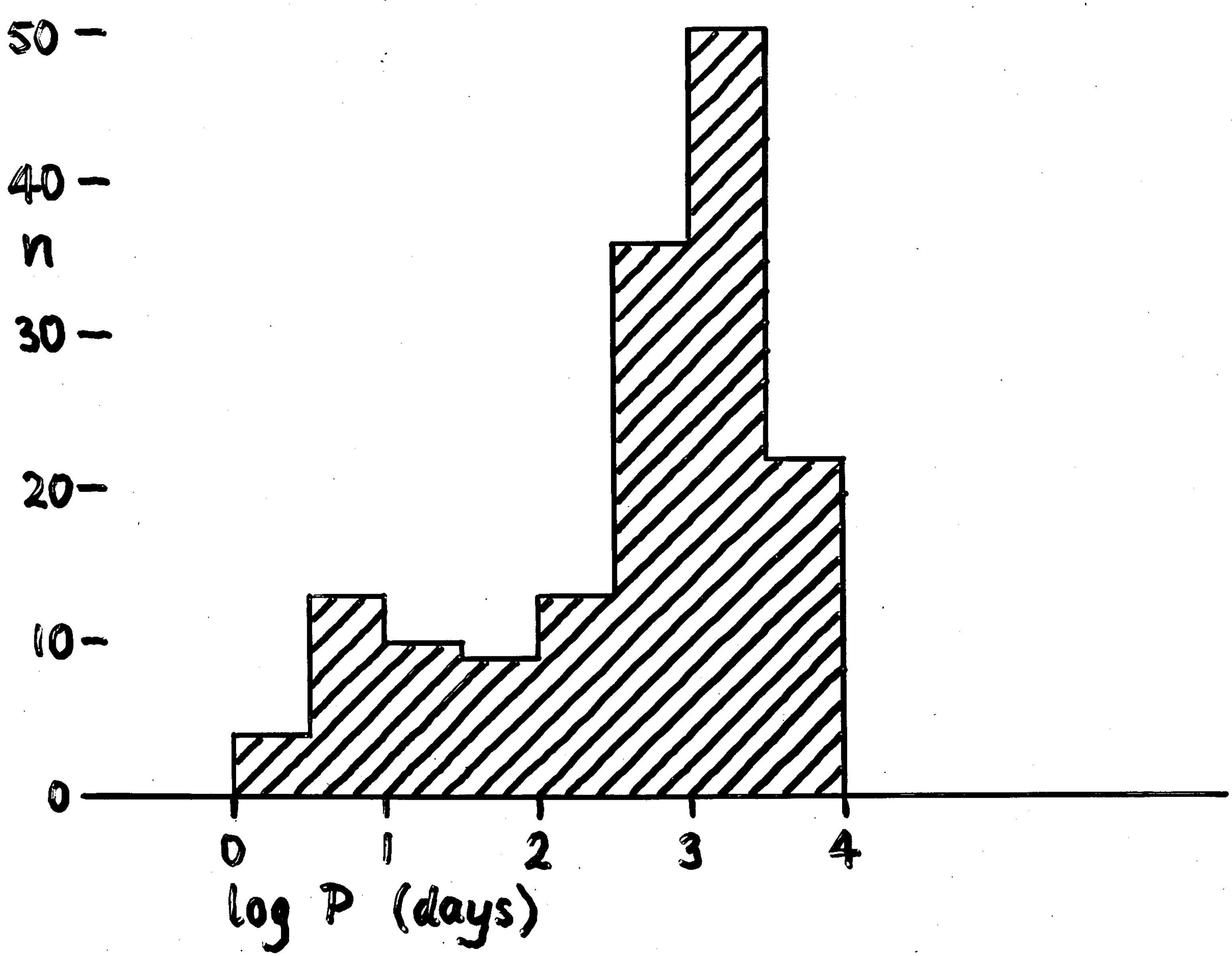
Lick Observatory, University of California
Santa Cruz, California

March 23-24, 1976

JESSE GREENSTEIN - CHAIRMAN

DRAFT

Spectroscopic Orbits (Papers 1-150)

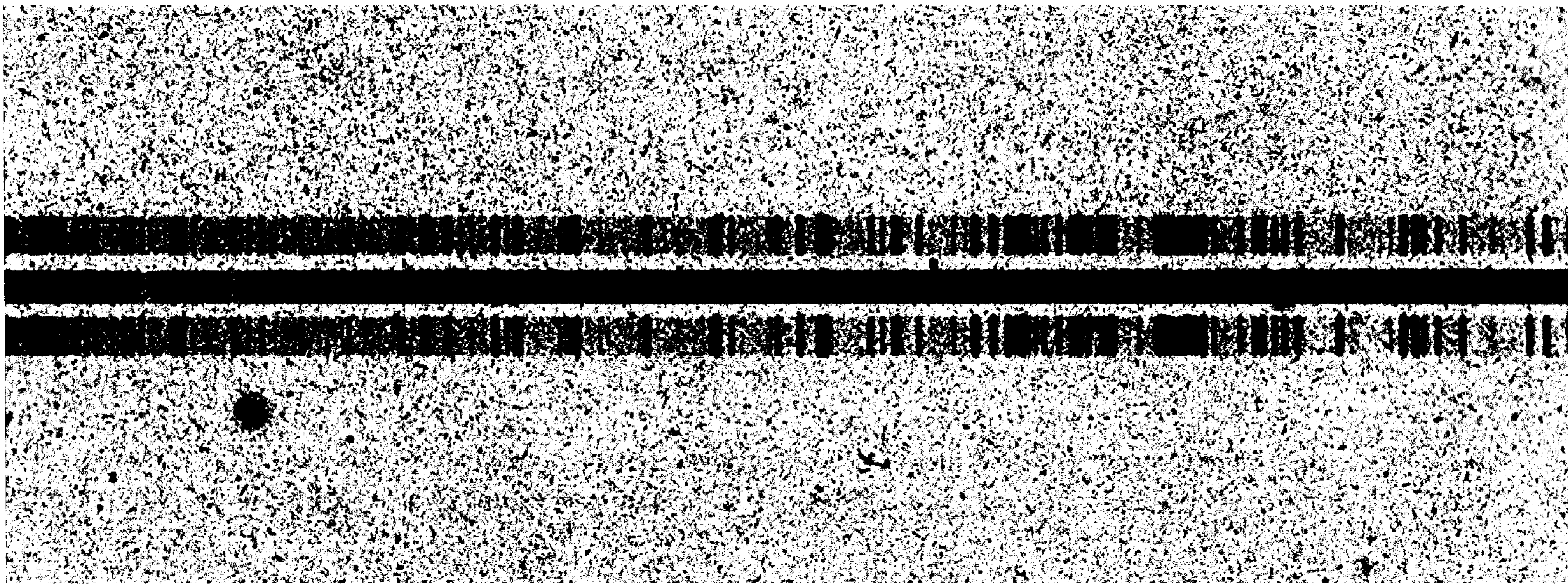


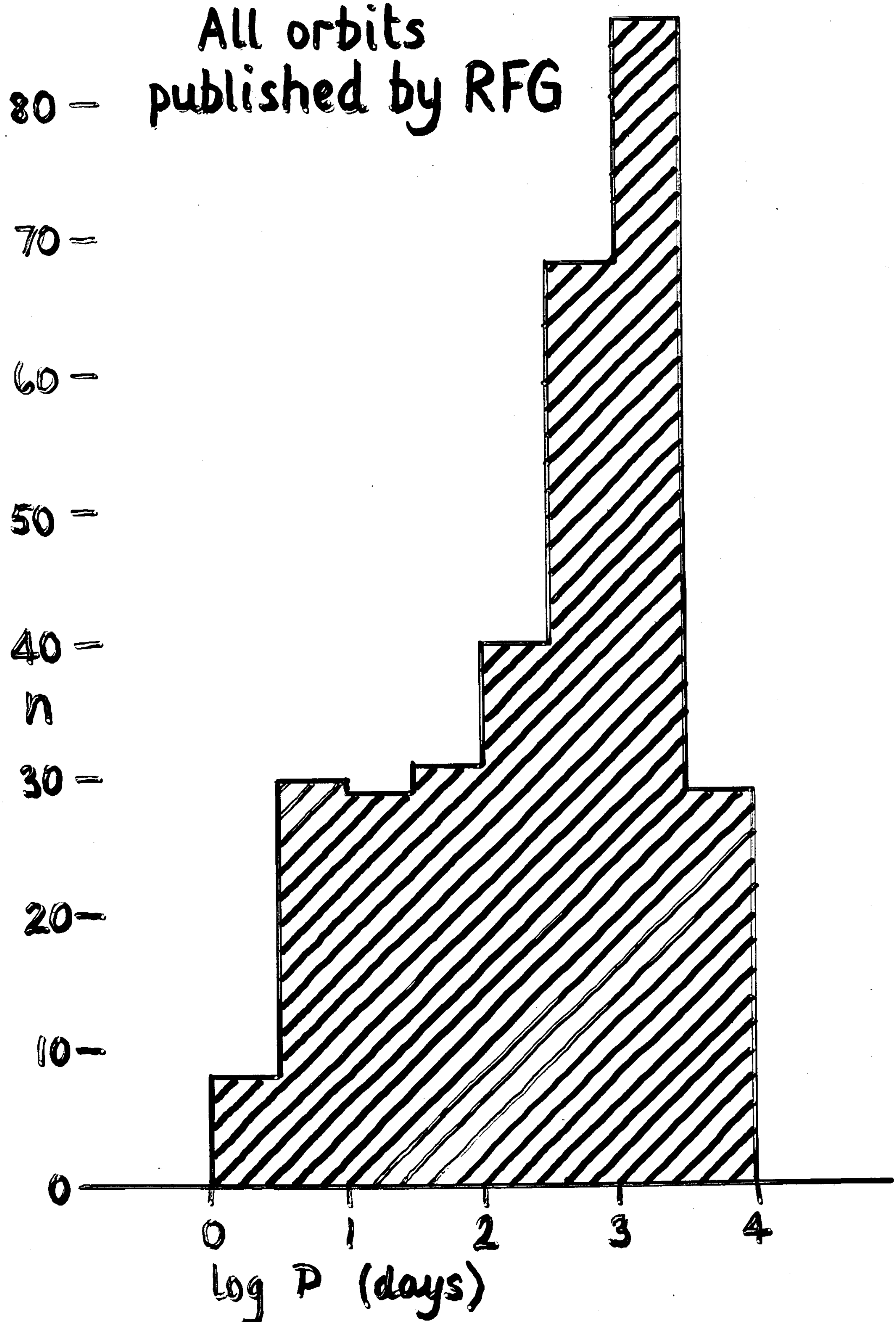
R. E. Wilson, General Catalogue of Stellar Radial Velocities (Carnegie Institution, 1953):

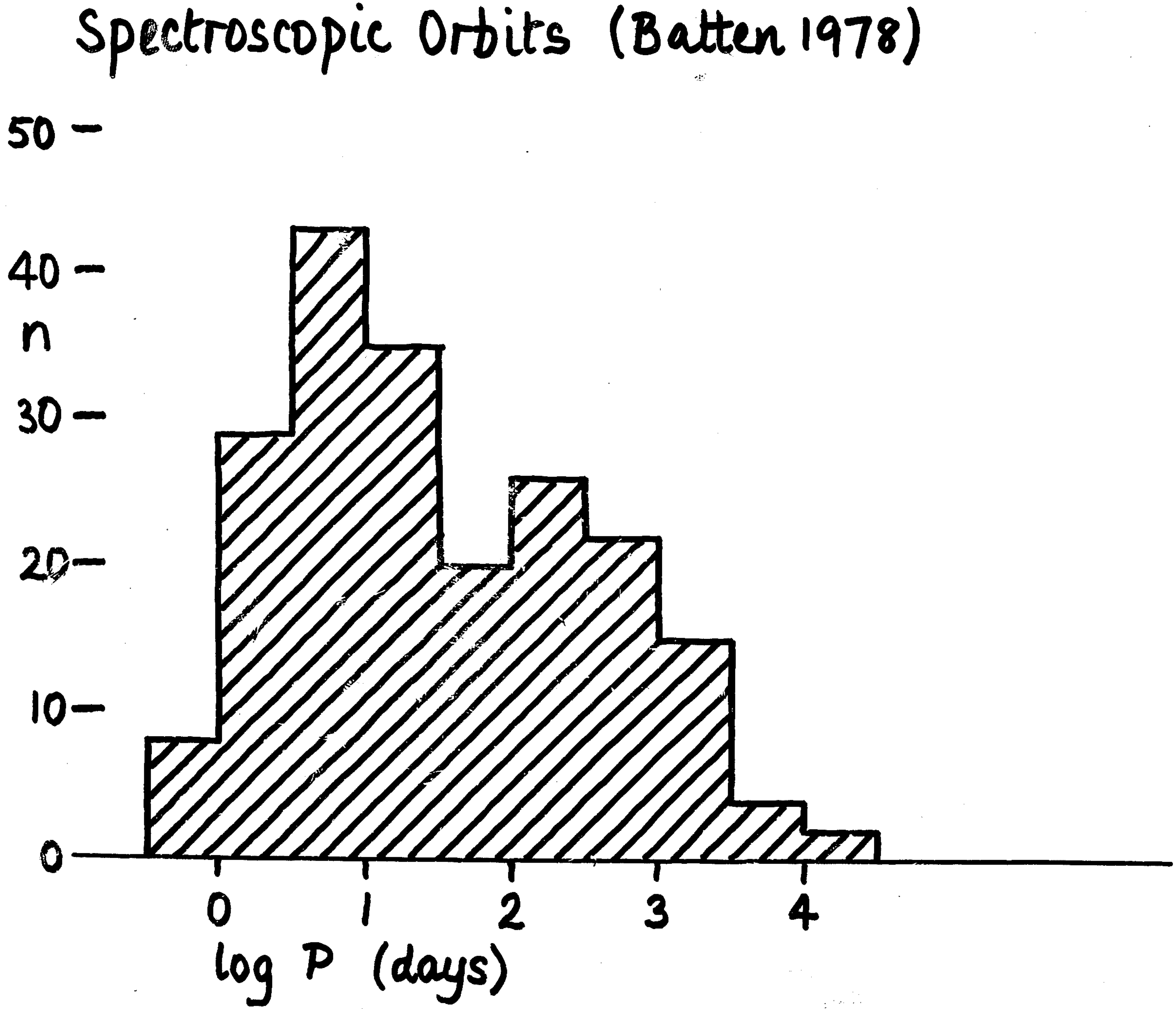
15,000 stars, but only
1500 with velocities good to ~ 1 km/s
(mostly with $\underline{V} < 5^m.5$, Lick Obs.)

Redman: DAO 72-inch
7^m K stars
Exposure 2 hours
90 Å/mm → 6 km/s s.d.

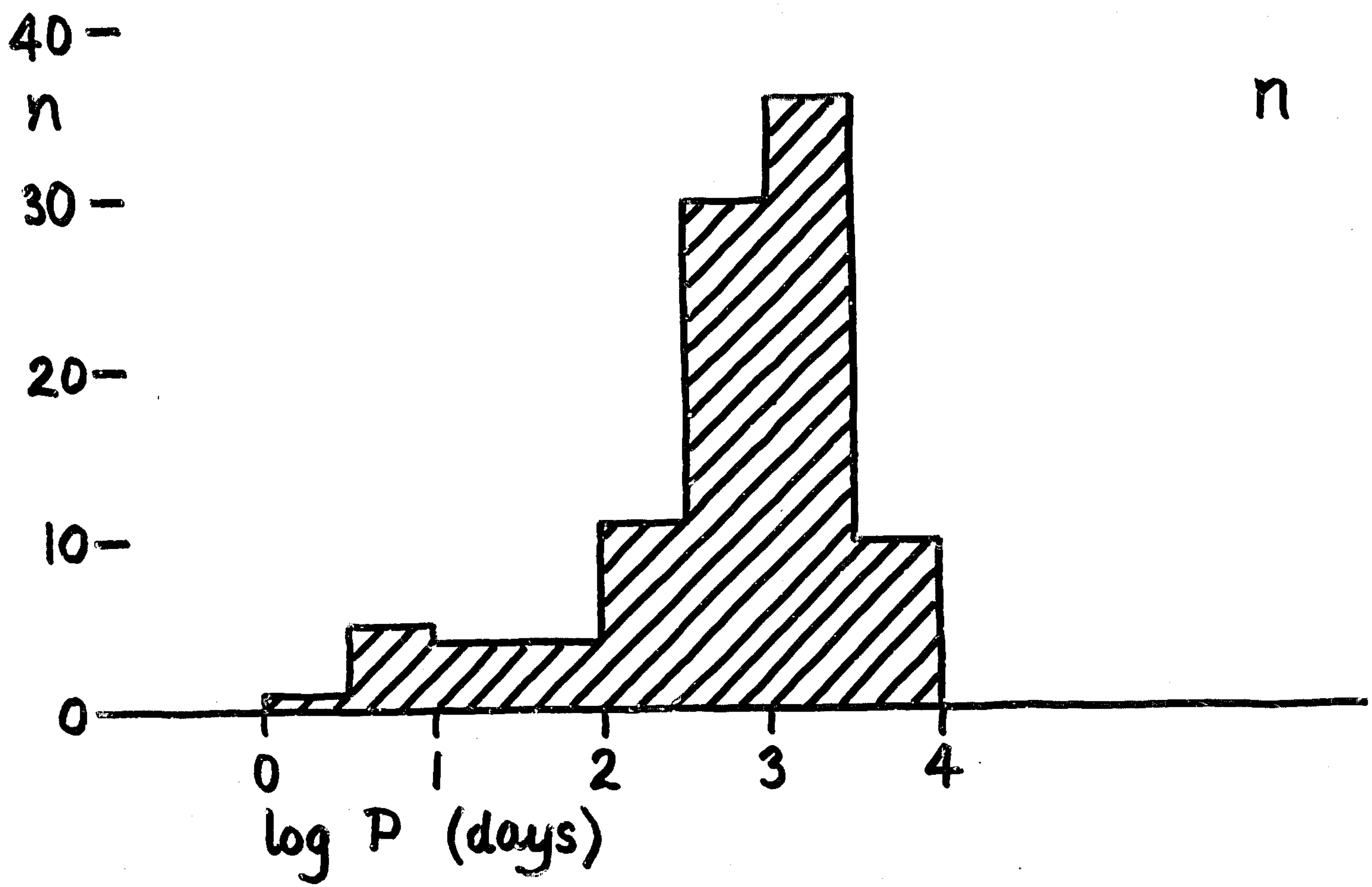
Cambridge: 36-inch
50 9^m stars in a night, ~~3~~ 1 km/s s.d.?




All orbits
published by RFG
80
70
60
50
40
n
30
20
10
0
0
1
2
3
4
log P (days)


Spectroscopic Orbits (Batten 1978)
50
40
n
30
20
10
0
0
1
2
3
4
log P (days)

Spectroscopic Orbits (Papers 1-100)



Michelson Summer School 2000

Wednesday 23 August Binary Stars

Stellar radial-velocity studies and orbital-element distributions

R.F. Griffin

Doppler, Fizeau, Abney. Keeler.
Henry Draper & Sir Wm Huggins; Vogel

Historical development of radial-velocity studies

Development of photographic spectrographs largely free from flexure and thermal drifts, notably at Lick (Campbell 1898, Campbell & Moore 1928) How plates were measured

The *Radial Velocity Catalogue* (Wilson 1953); stagnation of photographic efforts. Advantage of c.-c.; demonstrate

Development of the photoelectric method at Cambridge (Griffin 1967) and Palomar (Griffin & Gunn 1974), and with *Coravel* at Geneva (Baranne et al. 1979). Spectrometers employing multi-channel detectors with direct cross-correlation of the stellar spectrum with a numerical mask (Latham 1985)

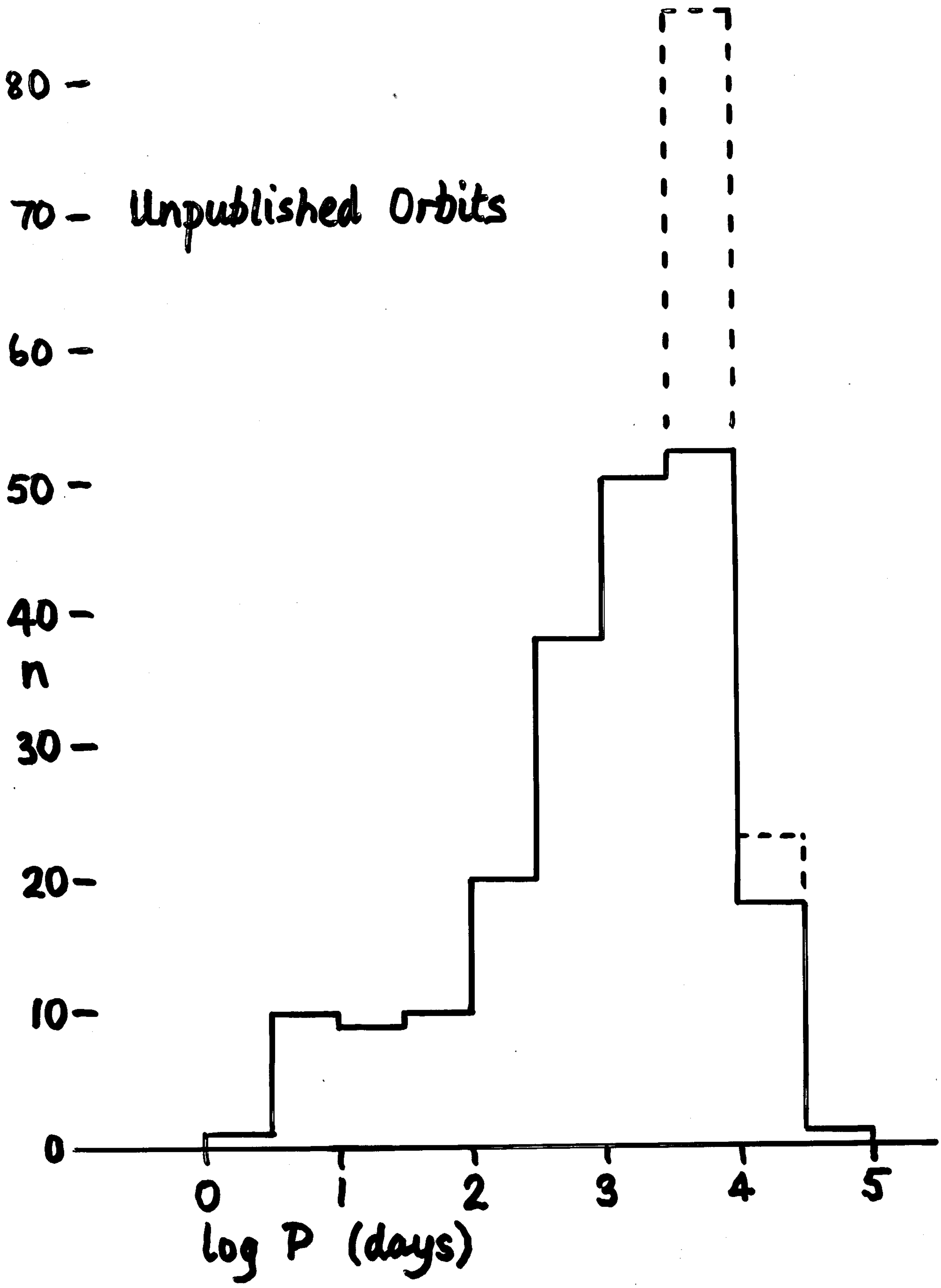
Development of techniques to measure radial velocities of high precision such as are needed to look for the reflex motions caused to stars by orbiting planets (Griffin 1973; every journal you look at nowadays). All high-precision instruments until comparatively recently have relied on imposing additional absorption lines on the stellar spectrum before it enters the spectrograph, in order to provide sufficiently reliable fiducial wavelengths (Young 1978, Smith 1982, telluric lines; McMillan & Smith 1987, F–P interferometer; Campbell, Walker & Yang 1988, HF; Marcy & Butler 1992, Cochran & Hatzes 1994, I_2). Through the use of image- and aperture-scrambling fibres, however, Baranne et al. (1996) have been able to dispense with the extra absorption lines and to return to the classical method of using an emission source for wavelength reference

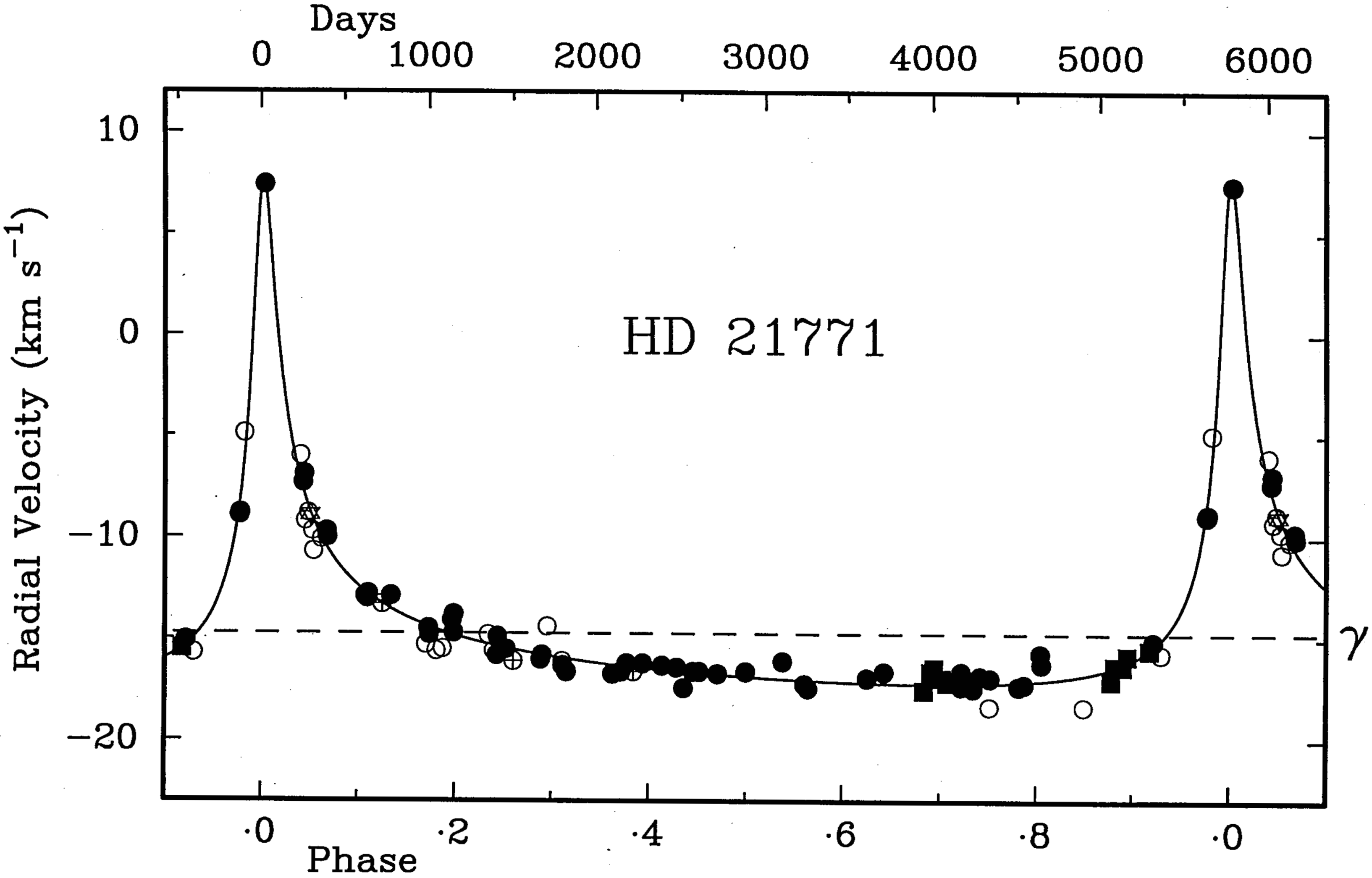
Orbital-element distributions

Previous compilations, *e.g. Observatory* **103**, 273, 1983; **111**, 291, 1991; **120**, 195, 2000, have graphically illustrated how the distribution of the periods known for spectroscopic binaries is hopelessly skewed by observational selection, which has been reduced in the speaker's own work. The matter is taken a little further in the talk. It is of great importance, because it is only now that there is becoming a significant overlap between the domains of spectroscopic and of 'visual' binaries, and without information from both techniques the masses of the stars concerned are in general indeterminate. The speaker cannot hope to duplicate the distribution of the periods of visual binaries, many of which are of centuries or millennia, but it seems encouraging to have shown already that the (logarithmically) most popular periods are at least several years, rather than the several days that they appeared to be only twenty years ago. Examples will be shown of spectroscopic orbits of long period, including two that are close to a century and one that is more. Currently continuing observations of certain other objects may be described.

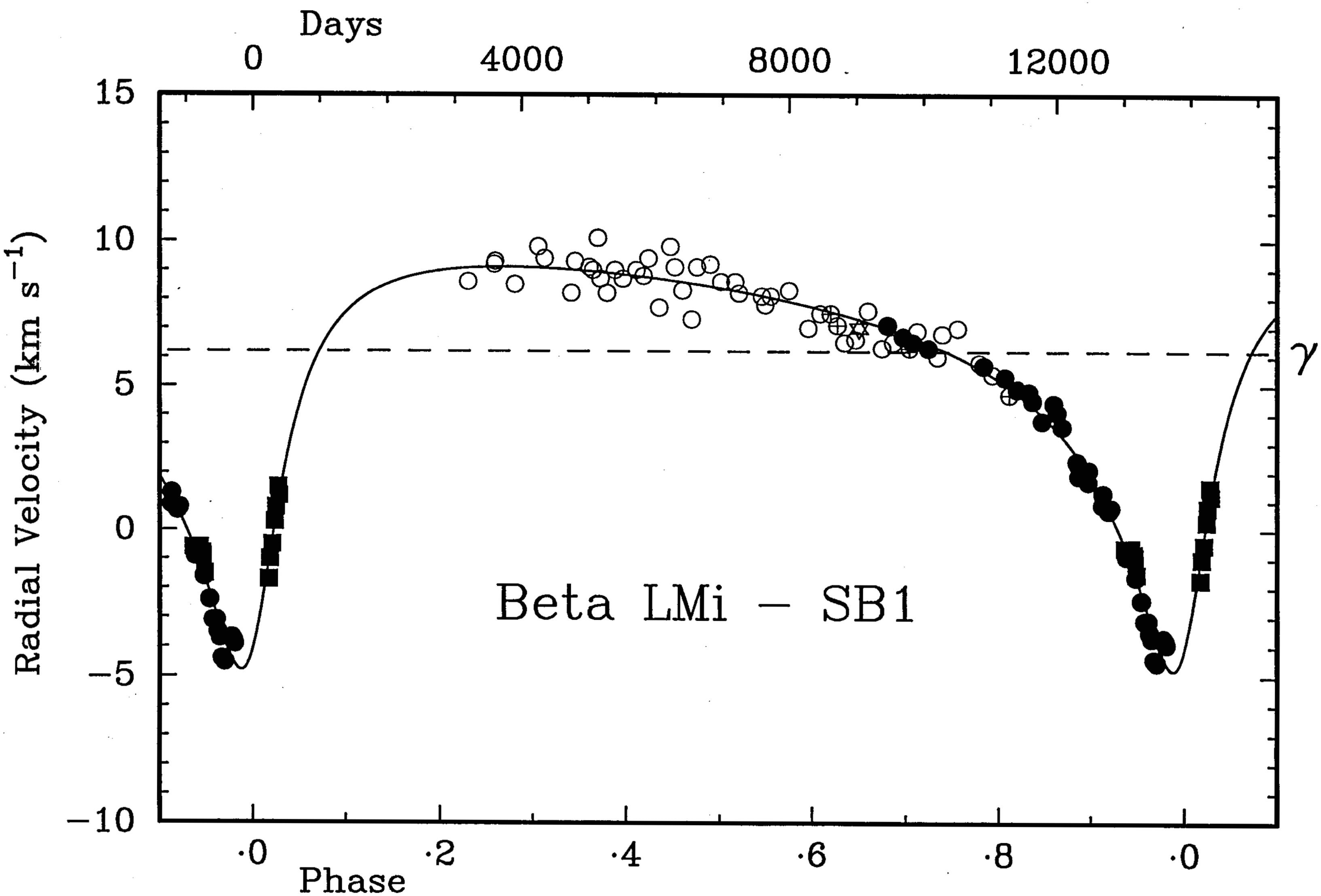
References

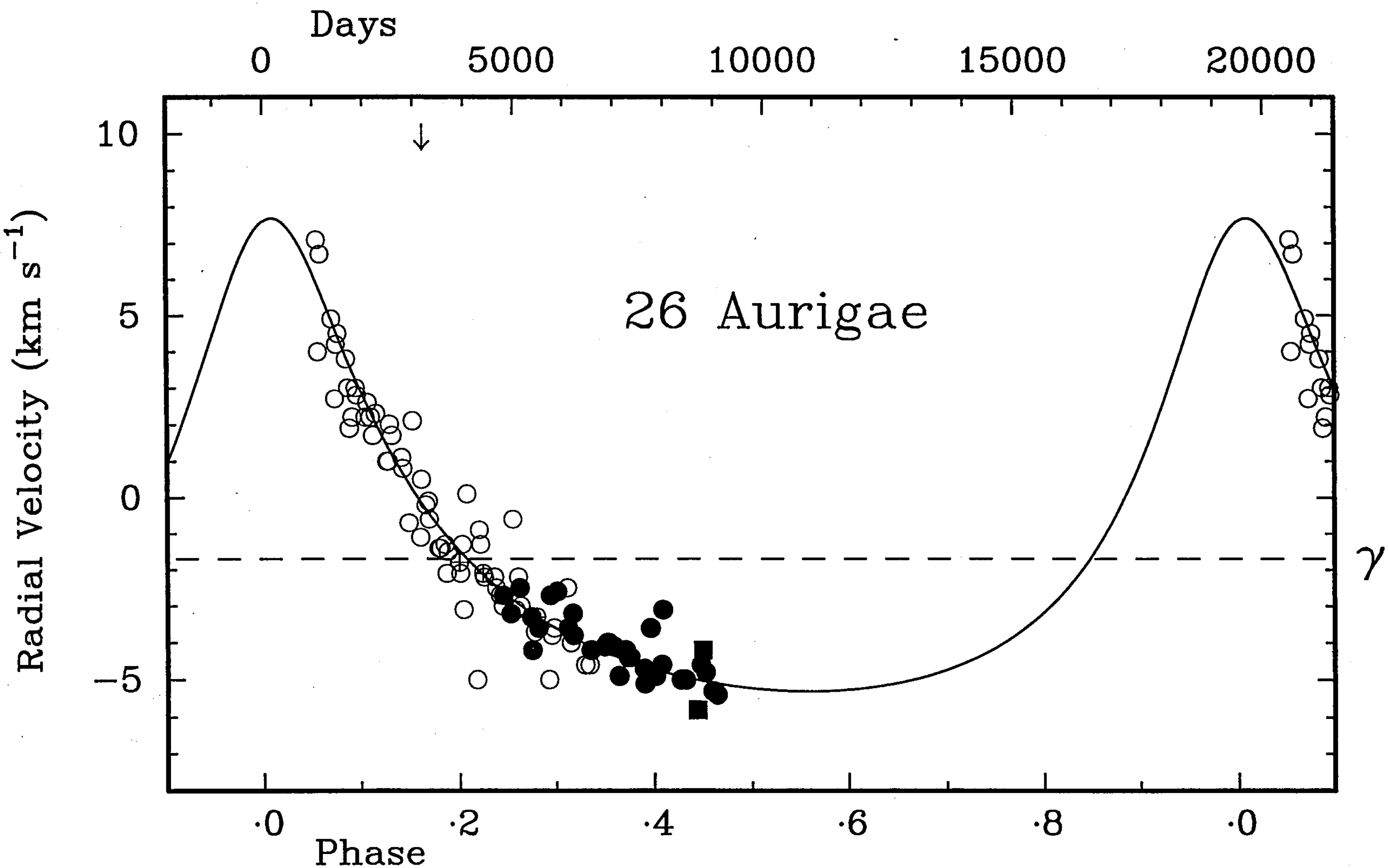
Baranne, A., Mayor, M. & Poncet, J.L. 1979, *Vistas in Astr.*, **23**, 279.
Baranne, A. *et al.* 1996, *A&AS*, **119**, 373.
Campbell, B., Walker, G.A.H. & Yang, S. 1988, *ApJ*, **331**, 902.
Campbell, W.W. 1898, *ApJ*, **8**, 123.
Campbell, W.W. & Moore, J.H. 1928, *Publ. Lick Obs.*, **16**, 1.
Cochran, W.D. & Hatzes, A.P. 1994, *ApSS*, **212**, 281.
Griffin, R.F. 1967, *ApJ*, **148**, 465.
Griffin, R.F. & Gunn, J.E. 1974, *ApJ*, **191**, 545.
Griffin, R.& R. 1973, *MNRAS*, **162**, 243.
Latham, D.W. 1985, in A.G.D. Philip & D.W. Latham (eds.), *Stellar Radial Velocities* (*IAU Coll.*, no. 88) (Davis, Schenectady), 1985, p. 21.
Marcy, G.W. & Butler, R.P. 1992, *PASP*, **104**, 270.
McMillan, R.S. & Smith, P.S. 1987, *PASP*, **99**, 849.
Smith, M.A. 1982, *ApJ*, **253**, 727.
Wilson, R.E. 1953, *General Catalogue of Stellar Radial Velocities* (Carnegie Institution of Washington, Washington, D.C.).
Young, A.T. *et al.* 1978, *Icarus*, **38**, 435.


80
70
Unpublished Orbits
60
50
40
n
30
20
10
0
0
1
2
3
4
5
log P (days)

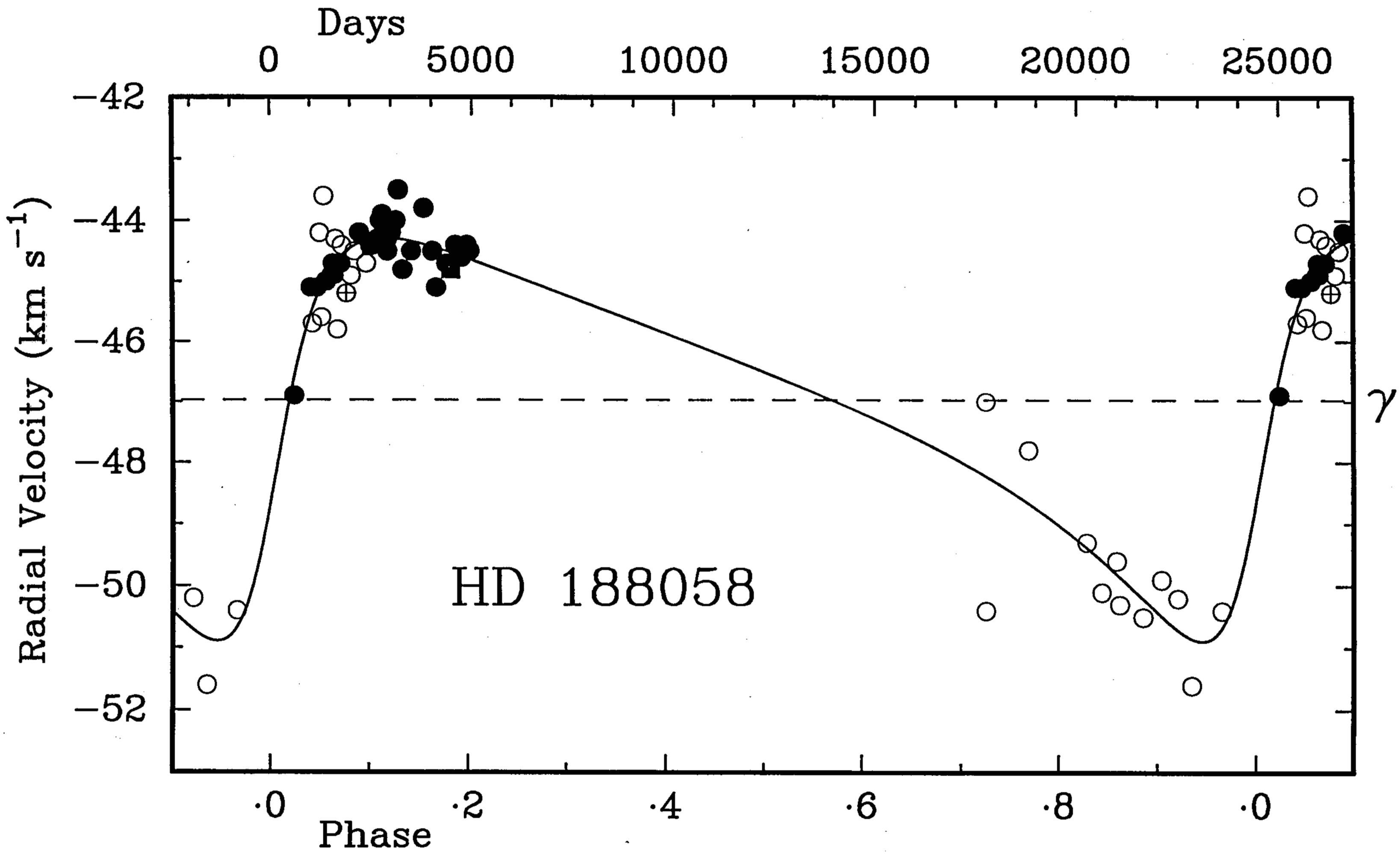


Days
0
1000
2000
3000
4000
5000
6000
10
0
−10
−20
Radial Velocity (km s^{-1})
HD 21771
γ
·0
·2
·4
·6
·8
·0
Phase

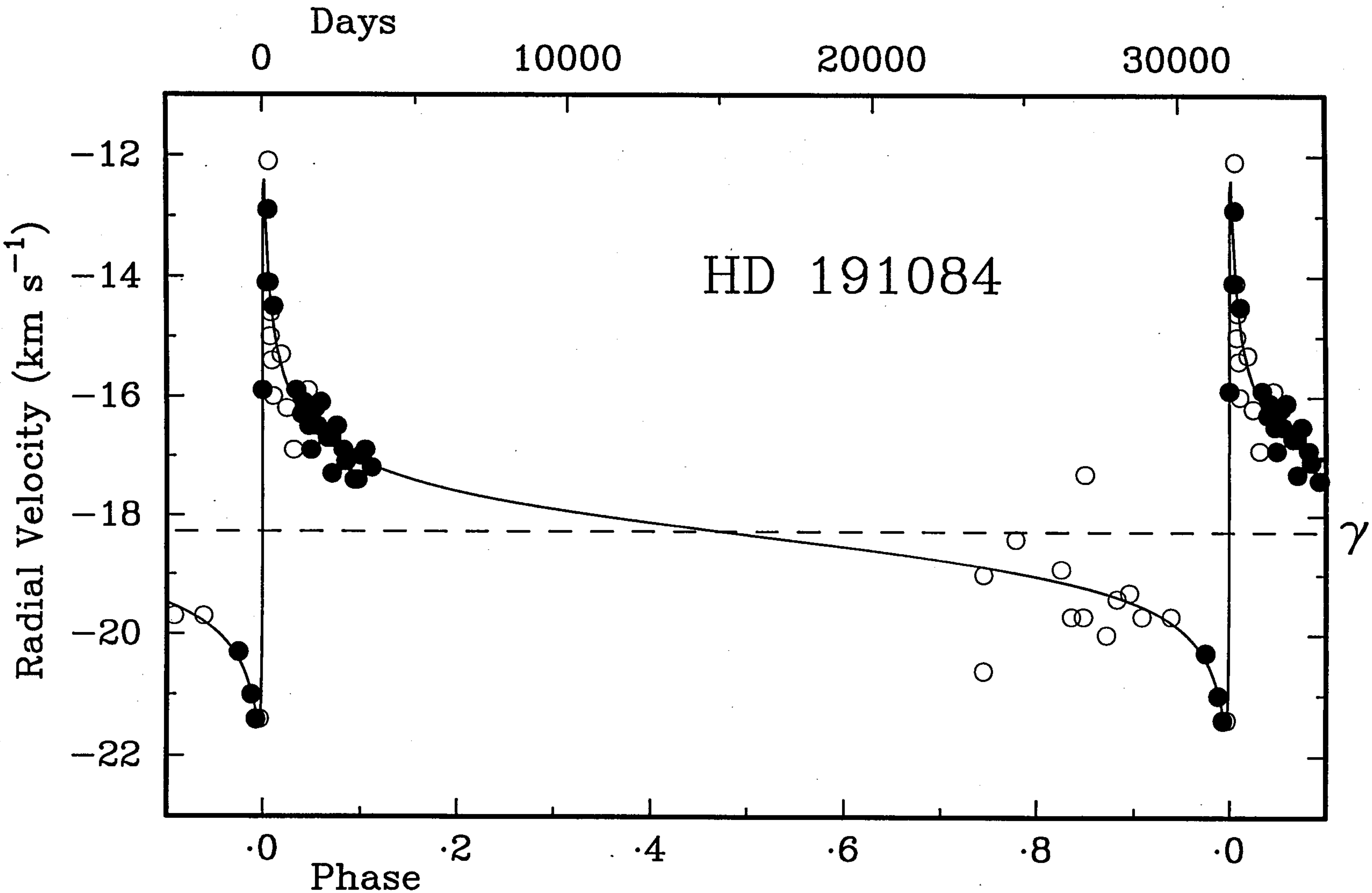

Days
0
4000
8000
12000
15
10
5
0
−5
−10
Radial Velocity (km s^{-1})
γ
Beta LMi – SB1
·0
·2
·4
·6
·8
·0
Phase

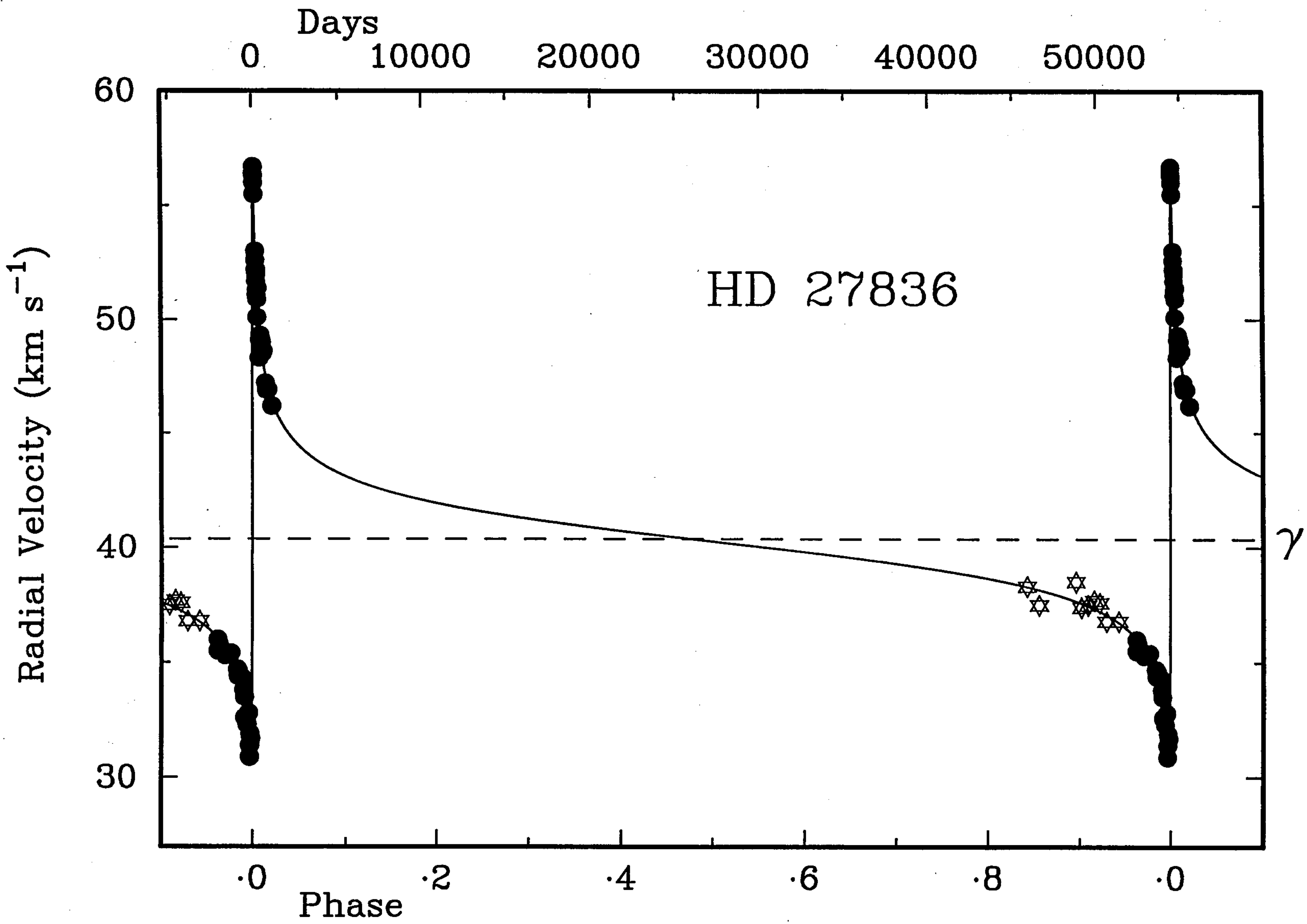


Days
0
5000
10000
15000
20000
10
5
0
−5
Radial Velocity (km s^{-1})
26 Aurigae
γ
·0
·2
·4
·6
·8
·0
Phase

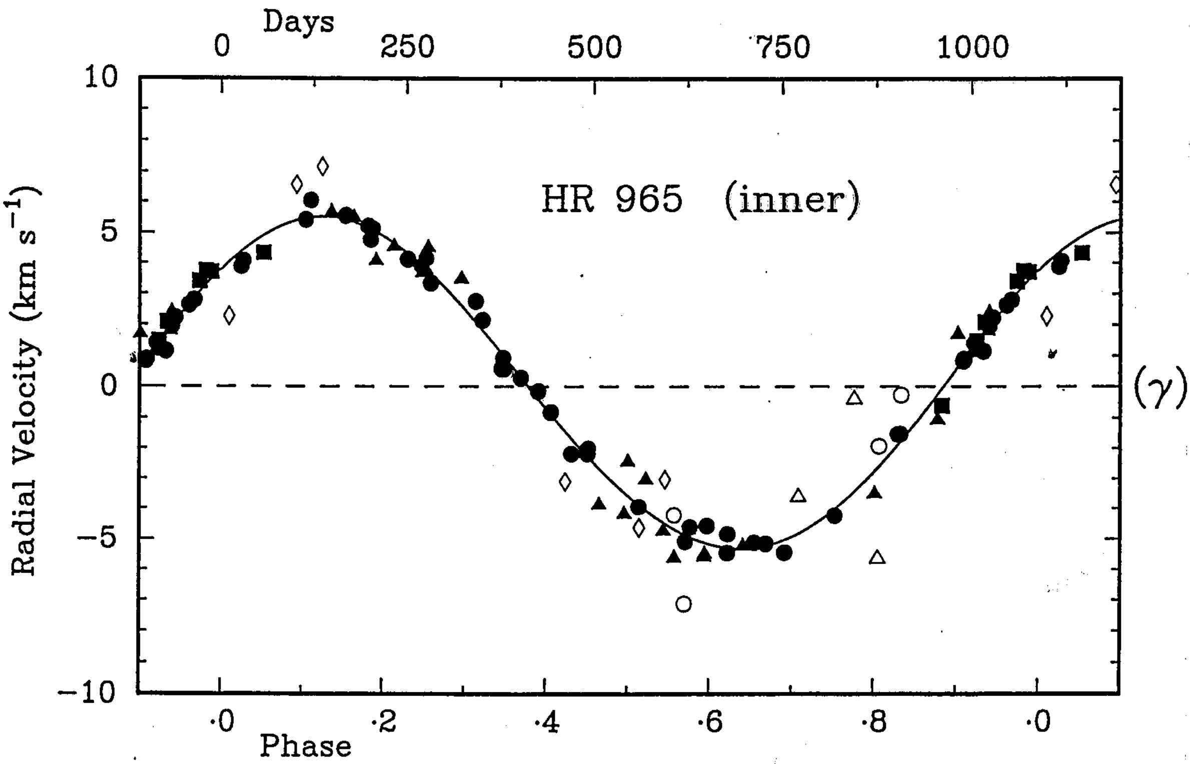


Days
0
5000
10000
15000
20000
25000
−42
−44
−46
−48
−50
−52
Radial Velocity (km s^{-1})
γ
HD 188058
·0
·2
·4
·6
·8
·0
Phase

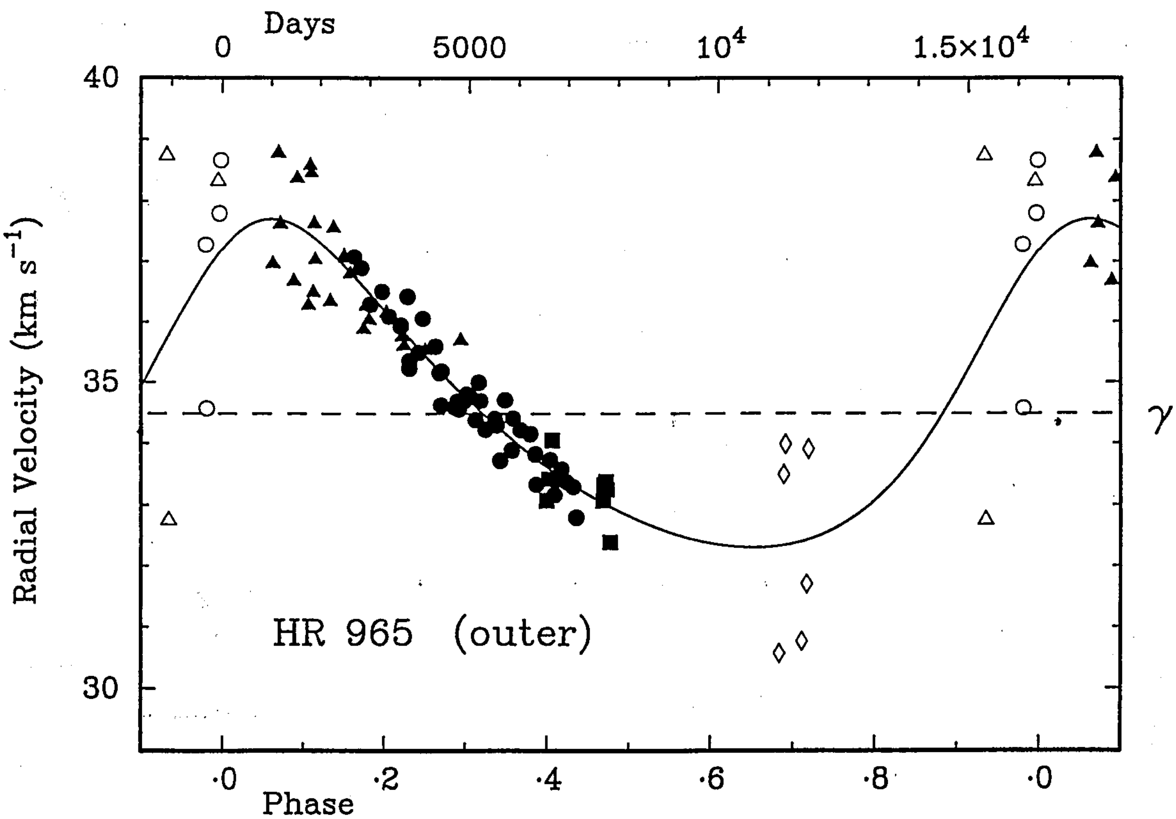

Days
0
10000
20000
30000
−12
−14
−16
−18
−20
−22
Radial Velocity (km s^{-1})
HD 191084
γ
·0
·2
·4
·6
·8
·0
Phase



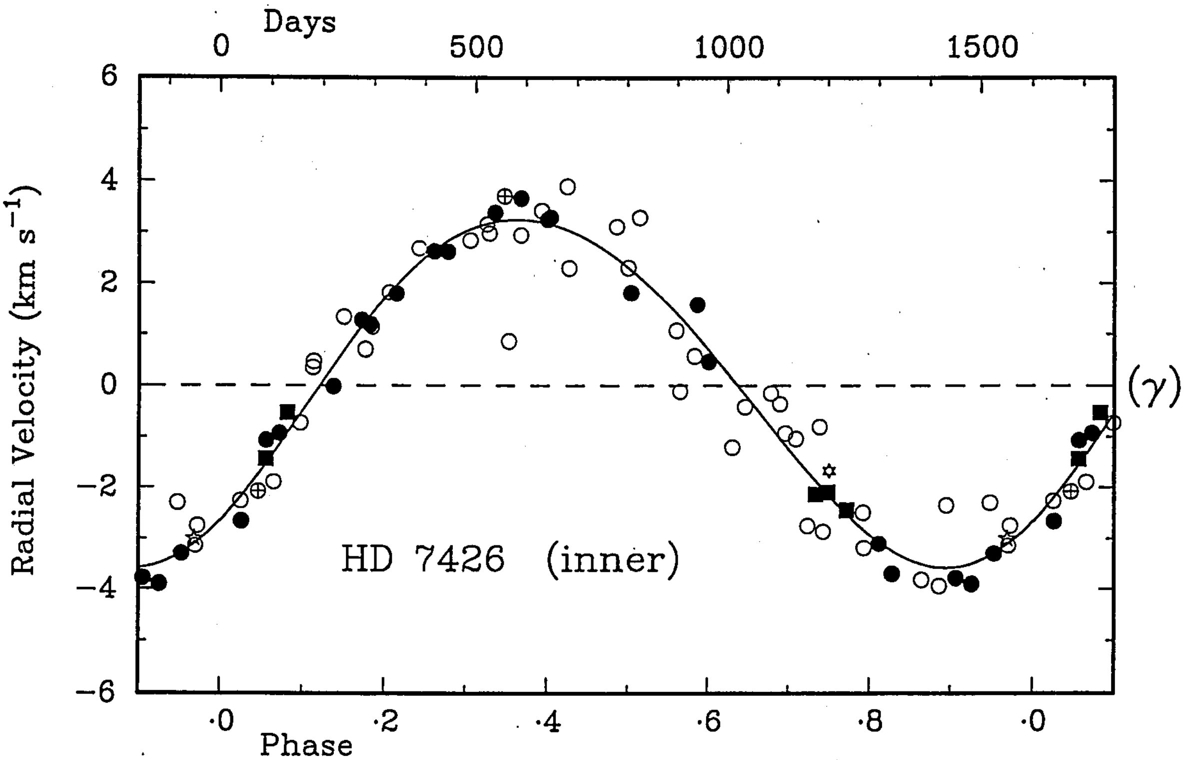
Days
0
10000
20000
30000
40000
50000
60
50
40
30
Radial Velocity (km s^{-1})
HD 27836
γ
·0
·2
·4
·6
·8
·0
Phase

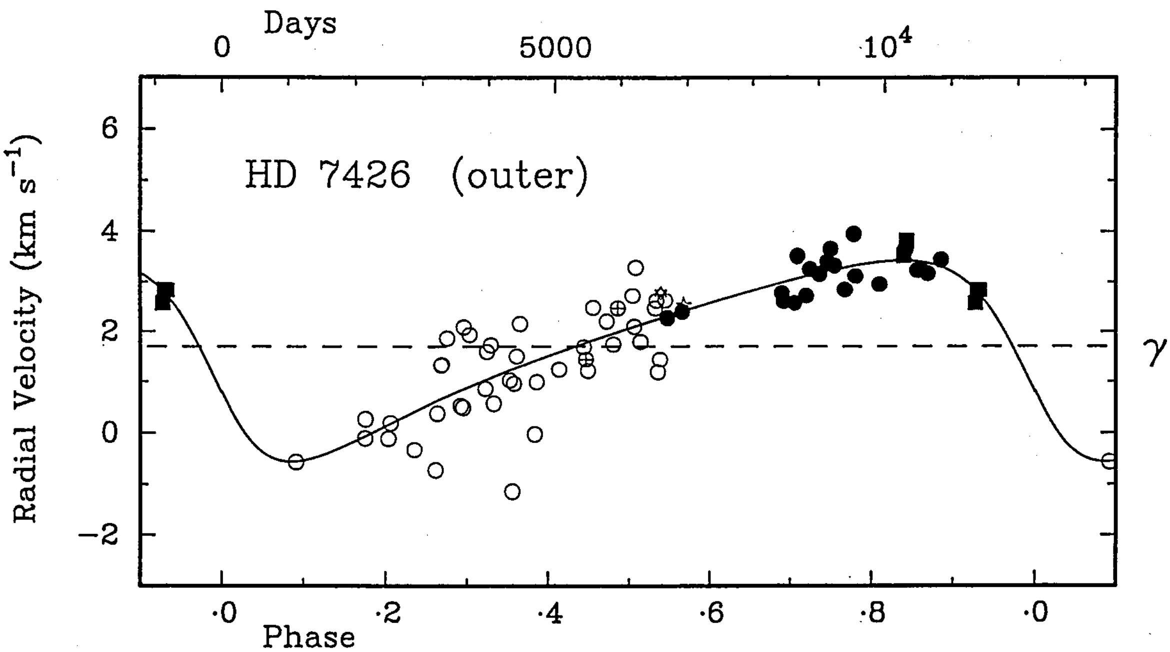


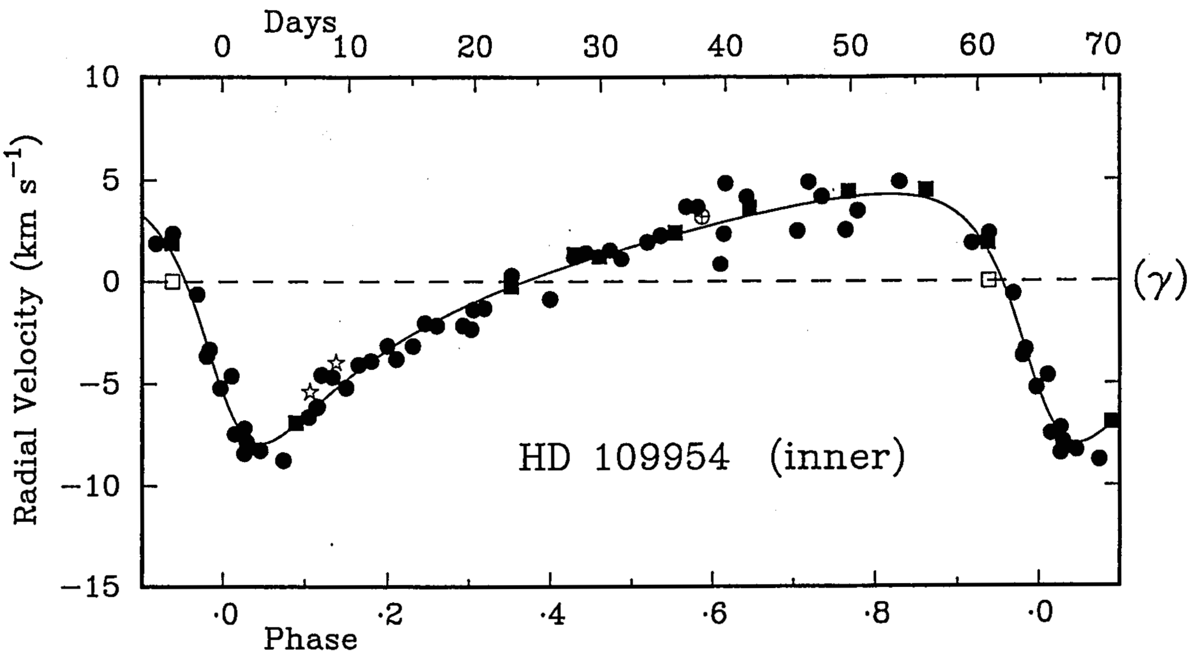
Days
0
250
500
750
1000
10
5
0
−5
−10
Radial Velocity (km s^{-1})
HR 965 (inner)
(γ)
·0
·2
·4
·6
·8
·0
Phase

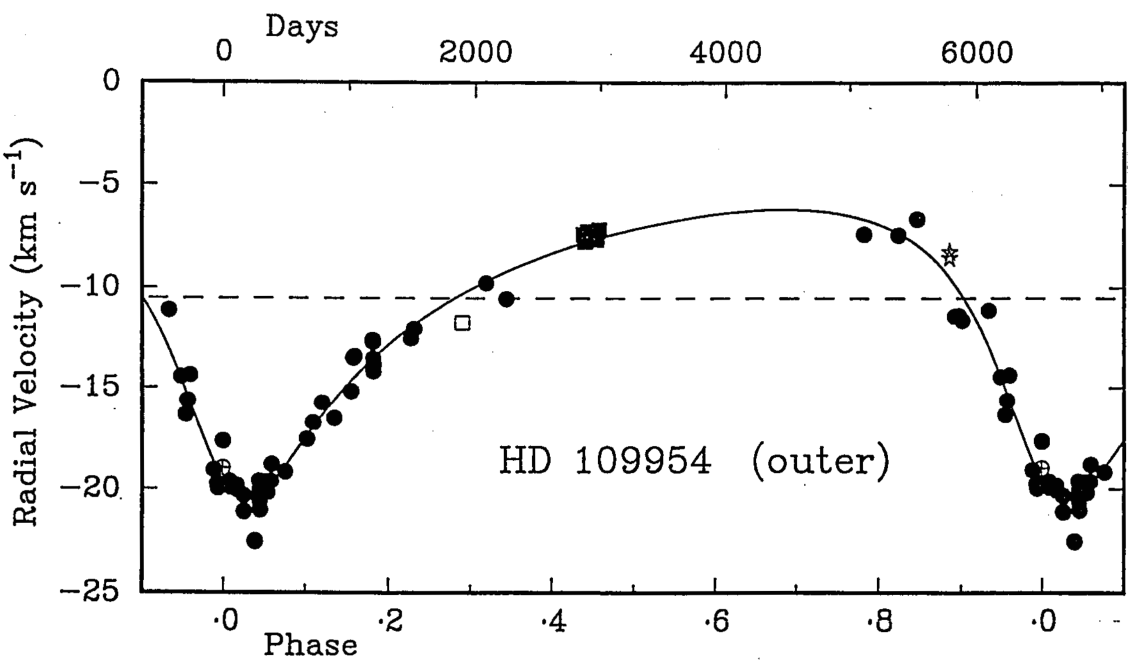


Days
0
5000
10^4
1.5×10^4
40
35
30
Radial Velocity (km s^{-1})
HR 965 (outer)
γ
·0
·2
·4
·6
·8
·0
Phase


Days
0
500
1000
1500
6
4
2
0
−2
−4
−6
Radial Velocity (km s^{-1})
(γ)
HD 7426 (inner)
·0
·2
·4
·6
·8
·0
Phase


Days
0
5000
10^4
6
4
2
0
−2
Radial Velocity (km s^{-1})
HD 7426 (outer)
γ
·0
·2
·4
·6
·8
·0
Phase


Days
0
10
20
30
40
50
60
70
10
5
0
−5
−10
−15
Radial Velocity (km s^{-1})
(γ)
HD 109954 (inner)
·0
·2
·4
·6
·8
·0
Phase


Days
0
2000
4000
6000
0
−5
−10
−15
−20
−25
Radial Velocity (km s^{-1})
γ
HD 109954 (outer)
·0
·2
·4
·6
·8
·0
Phase

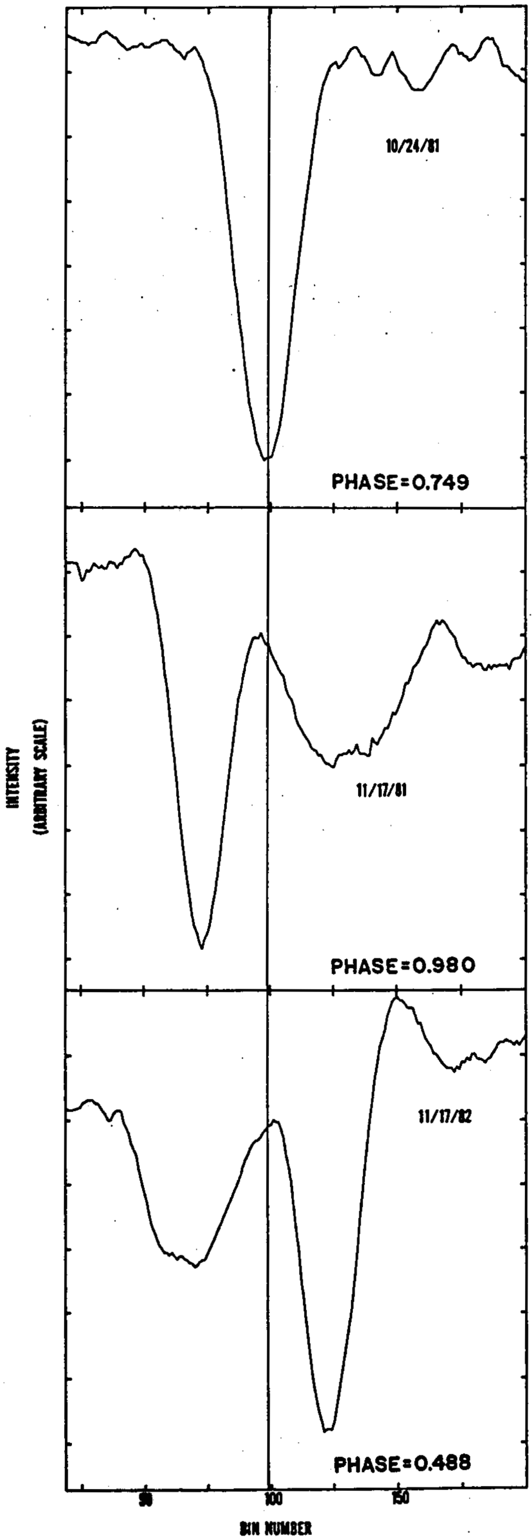


FIG. 1. Radial-velocity observations of Capella at three phases. The top frame shows an observation taken near conjunction, while the lower two frames are from times near maximum velocity separation. Note the width of the Ab (weaker) component in the lower two frames. The vertical line marks the location of the center-of-mass velocity for the Capella system.

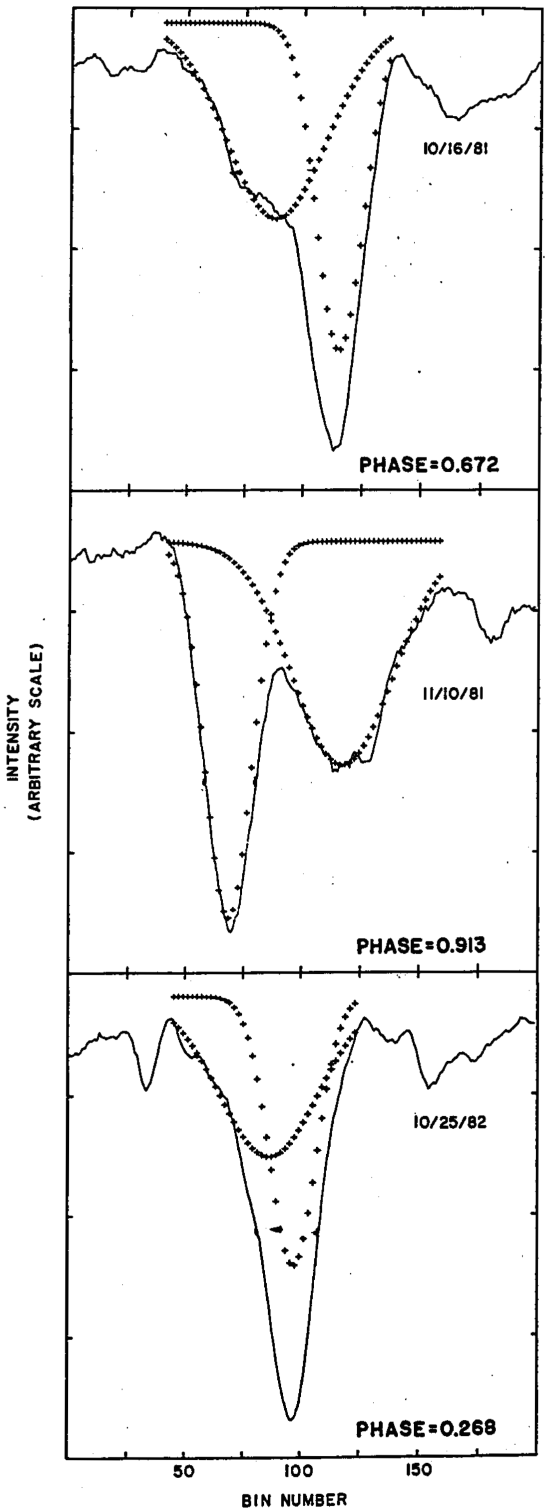


FIG. 2. Radial-velocity observations of Capella with the components blended. The solid line represents the actual observation record. The two Gaussian profiles (plus signs) were chosen to provide the best fit to the observation.

J. Astrophys. Astr. (1986) 7, 45–51

The Identity of the Primary Component of Capella

R. & R. Griffin *The Observatories, Madingley Road, Cambridge, England CB3 0HA*

Received 1985 October 1; accepted 1985 December 1

Abstract. Ever since the discovery in 1899 that Capella is a double-lined spectroscopic binary system the sharp-lined component, which has the later spectral type, has always been regarded as the primary (more luminous) star. However, traces obtained with radial-velocity spectrometers show that the broad-lined, earlier-type component is actually the primary.

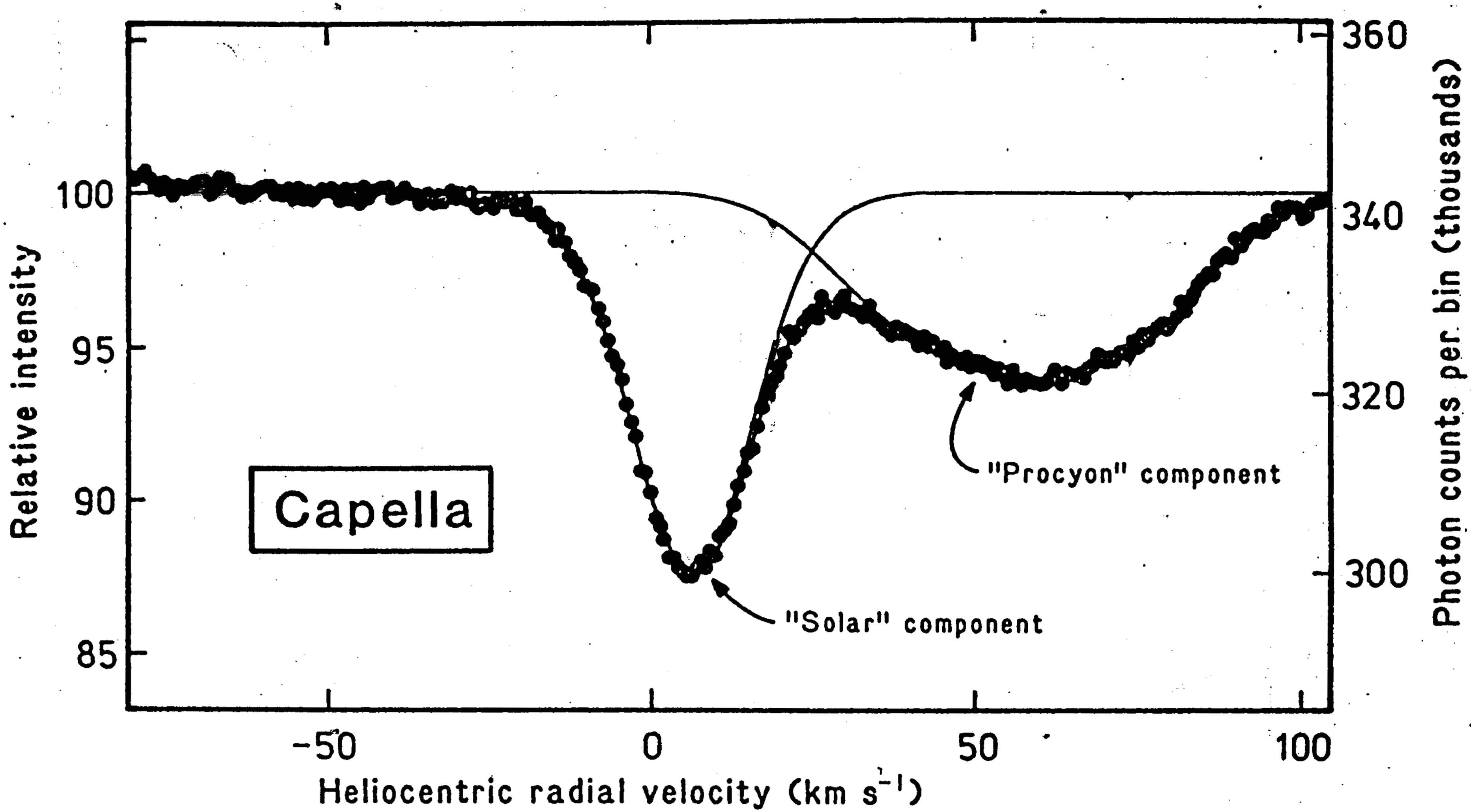
Key words: spectroscopic binaries—stars, individual

1. Historical introduction

The discovery that Capella (α Aur; HR 1708; HD 34029) is a spectroscopic binary was made by Campbell (1899, 1900) at the Lick Observatory and independently by Newall (1899, 1900) at our own observatory. Both discoverers recognized the spectrum as being double-lined, with one component much more conspicuous than the other; they considered the obvious component to be of approximately solar type. They lost no time in measuring its radial-velocity variations, and soon determined the orbit (Newall 1900; Campbell 1901; Reese 1901), which has a period of 104 days and a velocity semi-amplitude of about 26 km s^{-1}.

The other component of Capella manifests itself only as a shadowy contribution to the composite spectrum, and it is much to Newall's (1900) credit that he recognized its character well enough to call it the "Procyon" component.

Capella


Capella
"Solar" component
"Procyon" component
Relative intensity
Photon counts per bin (thousands)
Heliocentric radial velocity (km s^{-1})
100
95
90
85
360
340
320
300
-50
0
50
100

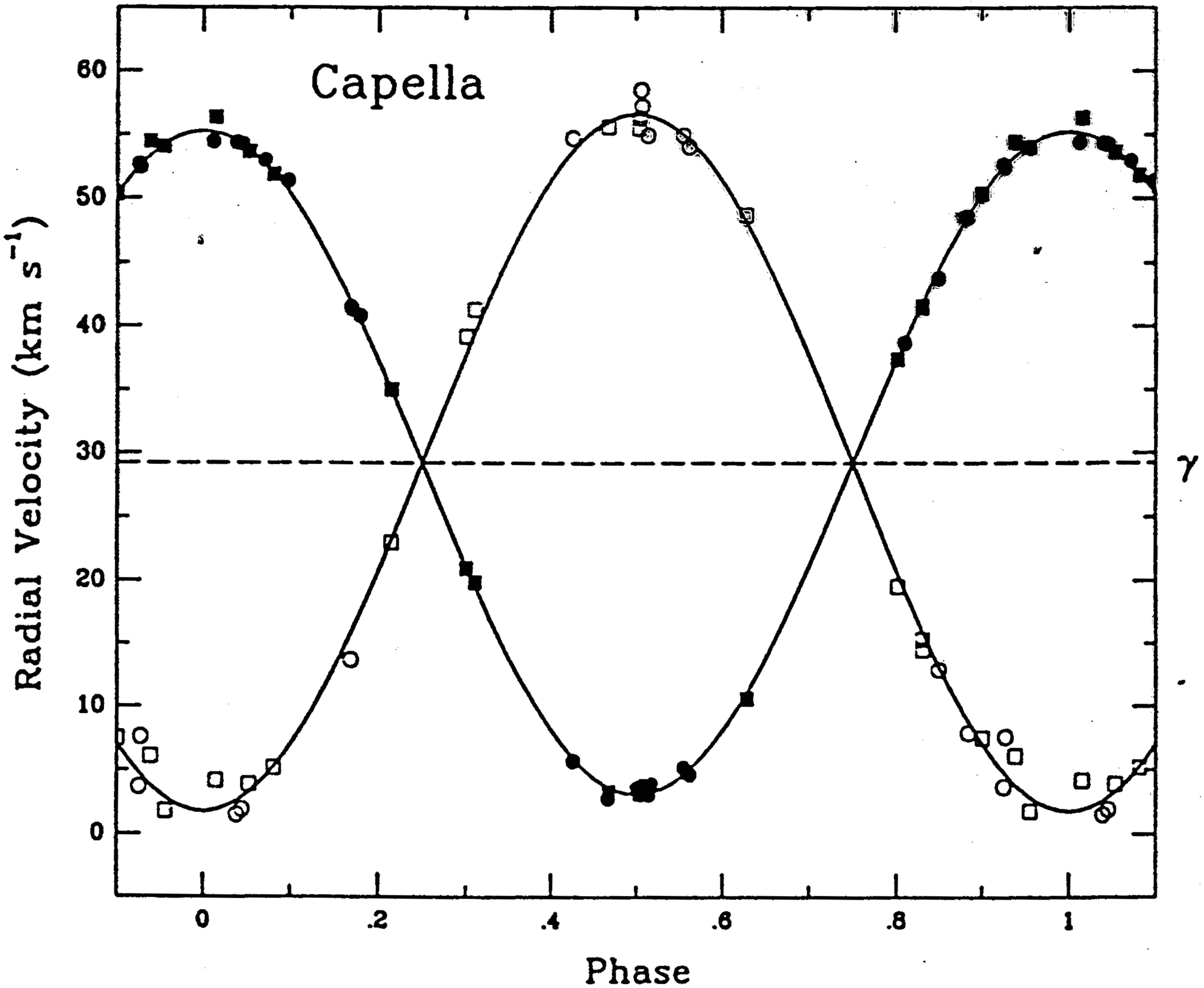
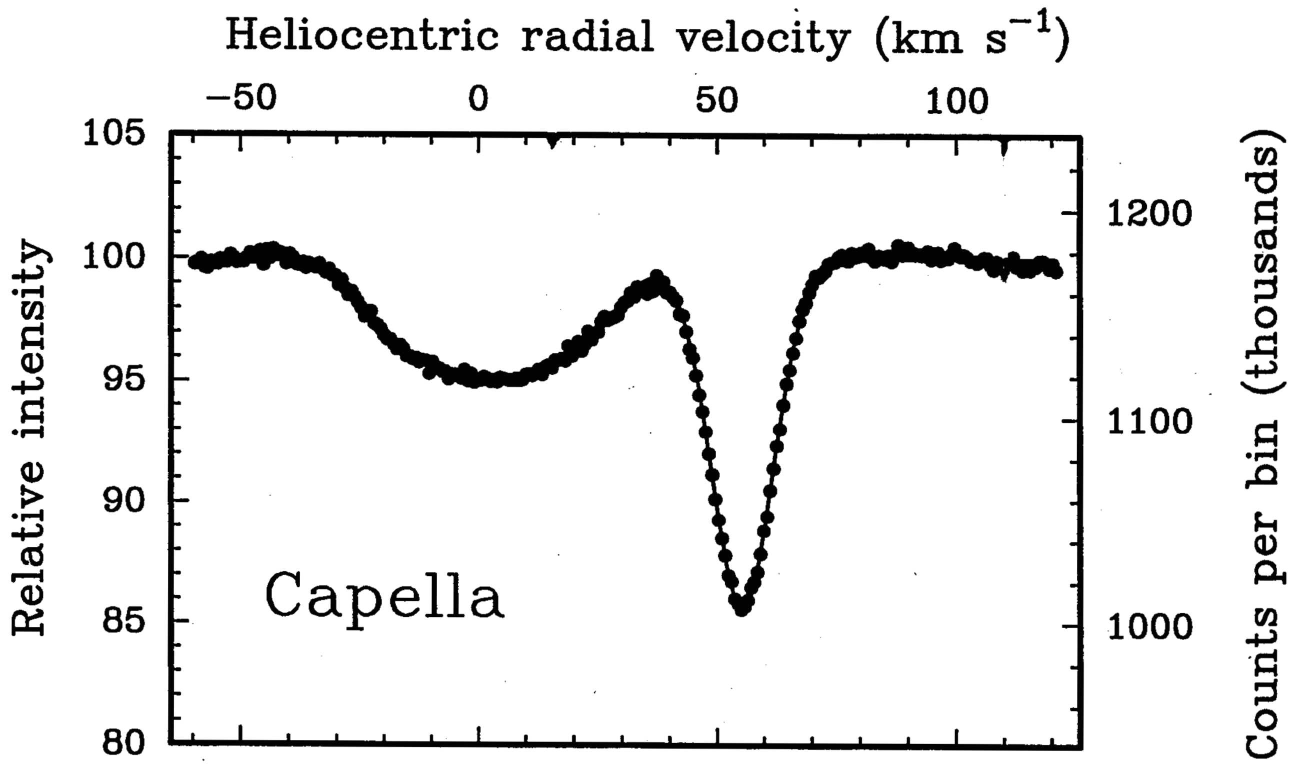
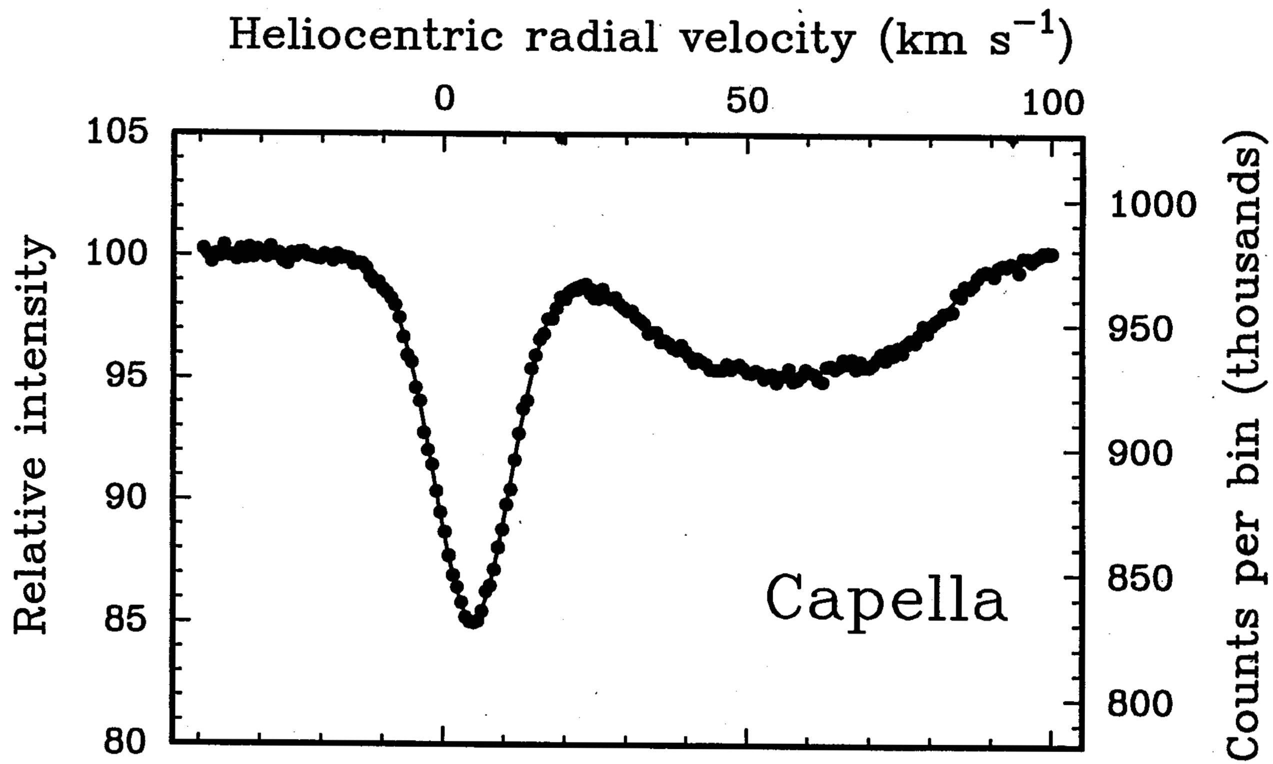


FIG. 3—The radial-velocity curves of the components of Capella. The data are from Table 1, and the curves represent the elements in Table 3. Filled symbols represent the velocities of the cooler star, and open ones those of the hotter. Squares represent the DAO data of Batten et al. (1991), and circles the new data from McDonald and KPNO.

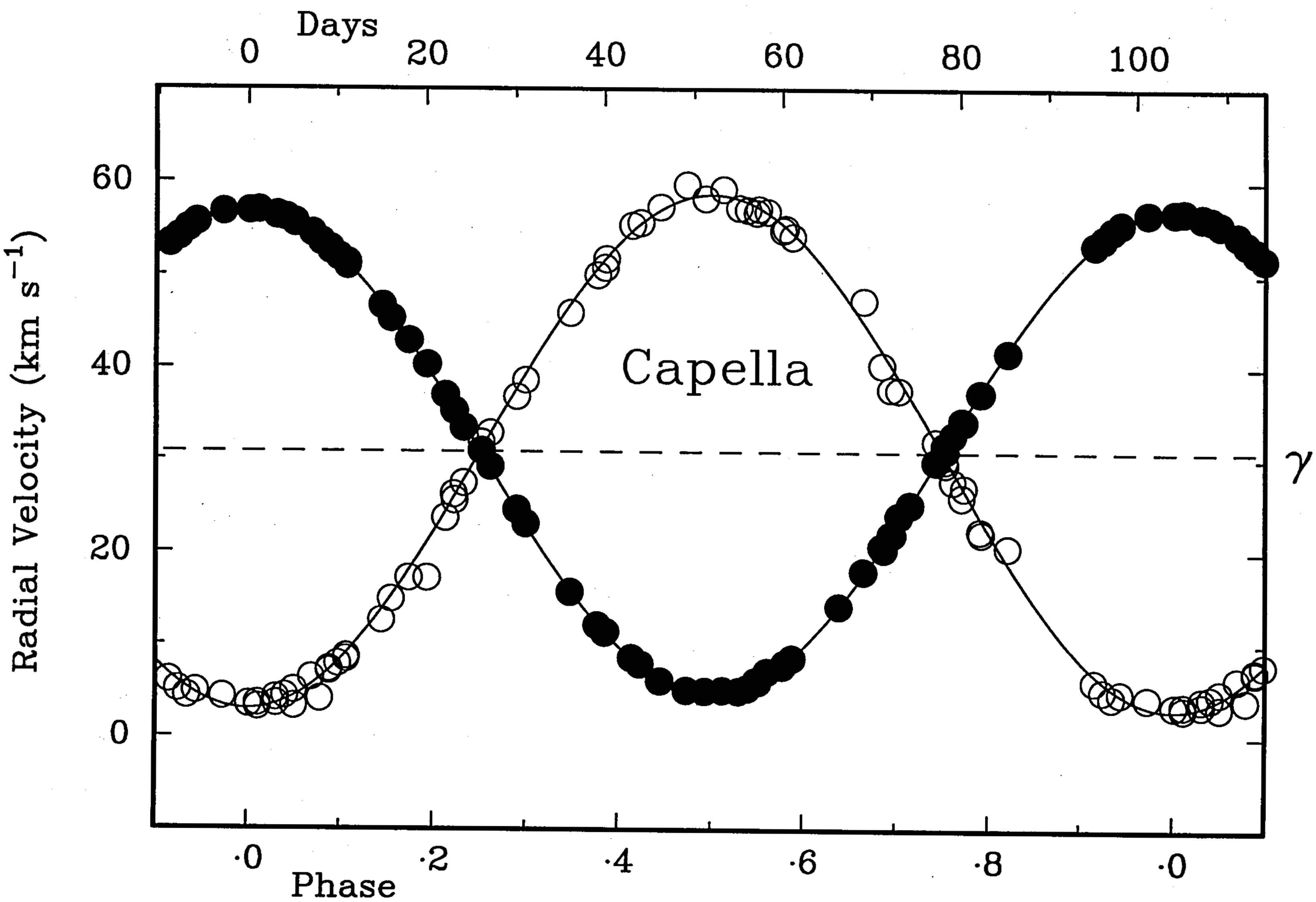
Barlow, Fekel & Scarfe 1993



Heliocentric radial velocity (km s^{-1})
−50
0
50
100
105
100
95
90
85
80
Relative intensity
1200
1100
1000
Counts per bin (thousands)
Capella



Heliocentric radial velocity (km s^{-1})
0
50
100
105
100
95
90
85
80
Relative intensity
1000
950
900
850
800
Counts per bin (thousands)
Capella


Days
0
20
40
60
80
100
60
40
20
0
Radial Velocity (km s^{-1})
Capella
γ
·0
·2
·4
·6
·8
·0
Phase